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DAMPING CHARACTERISTICS OF METAL MATRIX COMPOSITES(U)
MARTIN MARIETTA CORP DENVER CO ASTRONAUTICS GROUP
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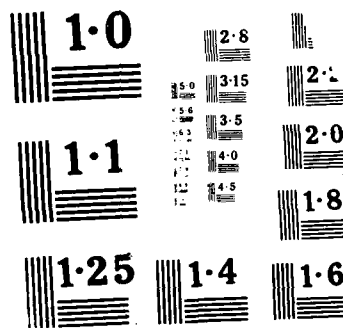
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Issue 7

Letter Report

Damping Characteristics of Metal Matrix Composites

Contract No. N00014-85-C-0857

Prepared for:

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Arlington, VA

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Quarterly Progress Report (#7)
(MCR-85-721)

- 1.0 Contract Number:
N00014-85-C-0857
- 2.0 Reporting Period:
8/11/87 — 12/9/87
- 3.0 ONR Scientific Officer:
Dr. Steven G. Fishman
- 4.0 Work Performed At:
Martin Marietta Astronautics Group, Denver, CO 80201
- 5.0 Principal Investigator:
Mohan S. Misra
- 6.0 Project Title:
Damping Characteristics of Metal Matrix Composites
- 7.0 Description of Research:
- 7.1 Objectives of Present Research

- Metal matrix composites (MMC) with enhanced material damping can be potential structural materials to improve significantly the stability, control and reliability of space structures. Objectives of this investigation are:

- Identify the mechanisms and sources of damping in continuous fiber-reinforced MMC (Gr/Al and Gr/Mg) using in situ characterization techniques.
- Determine the role of microstructural parameters (fiber volume, fiber orientation, interfiber spacing, grain size, precipitate morphology) in damping.
- Define the role of the fiber-matrix interface in damping.
- Develop high damping structural materials for space applications.

7.2 Summary of Work Accomplished During Previous Reporting Period

- Damping Behavior of Gr/Mg Composites

- Preliminary damping measurements were made in the kilohertz range using the Marx piezoelectric composite oscillator at $f = 80$ kHz. Both $[0^\circ]$ P55Gr/Mg-1%Mn and $[0^\circ]$ P55Gr/Mg-1%Zr exhibited strain amplitude dependent damping for $\epsilon > 10^{-6}$ with a maximum occurring at $\epsilon = 8 \times 10^{-5}$.
- Analysis of these damping data indicated that Gr/Mg-1%Mn displayed the $\psi_H = C_1/\epsilon \cdot \exp(-C_2/\epsilon)$ dependence predicted by Granato-Lucke (G-L) dislocation damping theory. In addition, the G-L strain amplitude dependence predicts a maxima in damping at $\epsilon = 2C_2$ for standing-wave sinusoidal strain distributions found in the piezoelectric oscillator pair technique.
- Low frequency flexural damping measurements of P55Gr/Mg-1%Mn and P55Gr/Mg-1%Zr exhibited both strain amplitude dependence and higher damping than corresponding Gr/Al specimens at low strain levels.
- Initial heat treatment of Gr/Mg composites (6 hours at 450°F) was conducted to optimize grain size and precipitate distribution to increasing the damping. The effect of changes in microstructure on

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damping were evaluated by a Marx piezoelectric composite oscillator apparatus ($f = 80$ kHz) before and after heat treatment. Gr/Mg composites exhibited an increase in damping as a result of the heat treatment.

- Fabrication of Gr/Mg Tubes by Centrifugal Casting Technique

- An optimum combination of process parameters such as preheat temperature of the mold, rpm and superheat temperature of molten magnesium is essential to ensure good matrix infiltration. An annular heating unit (stationary) was installed around the mold to maintain a uniform preheat temperature of the fiber preform at the time of pouring.
- Utilizing this test setup, five 2" diameter, 4" long Gr/Mg tubes were cast at 2900 rpm. Four tubes showed poor matrix infiltration and partial trapping of the graphite fibers by magnesium because of difficulties encountered during the casting process such as low preheat temperature of the tundish, slippage and loss of preform (within the mold) and low pouring temperature of the molten magnesium. The remaining cast tube showed regions of good matrix infiltration, suggesting that Gr/Mg tubes can be cast successfully by filament winding/centrifugal casting process with optimum process parameters.

7.3 Progress During this Reporting Period

- Damping Measurements of Gr/Mg Composites

- To increase further the damping of the Gr/Mg composites, another heat treatment of 800°F for 4 hours (8 hours with thick specimens) was performed to obtain a larger grain size ($> 10 \mu\text{m}$). Preliminary damping tests using small piezoelectric composite oscillator specimens indicates that this heat treatment did increase the overall damping of this composite system (Fig. 1). Once again, the characteristic peak in the damping was evident at the higher strain amplitudes.

- In Situ Characterization of Metal Matrix Composites

Stress Pattern by Thermal Emission (SPATE)

- SPATE investigations have been conducted with diffusion bonded P55Gr/6061Al composites to correlate stress concentrations with specimen flaws. Specimens were fabricated using a modified state-of-the-art diffusion bonding techniques, with "windows" cut into the top face sheet to facilitate easier viewing of the interfaces. Stress levels as large as 321.6 to 344.8 MPa (46.6 to 50.0 ksi) were observed directly above fiber bundles as shown in the SPATE scan in Figure 2. These values are higher than the yield strength of 6061-T4 alloy of 131.0 MPa (19.0 ksi) and are commensurate with localized plastic deformation near the fiber-matrix interface observed by Moire interferometry earlier in this program.

Acoustic Emission (AE)

- Acoustic emission testing of flat Gr/Mg specimens were conducted to isolate and to identify AE sources. All specimens in this preliminary investigation were as-cast and were tested in tension to failure. Small, burst-like AE were observed at low loads, while some RMS liftoff can be seen above this point as shown in Figure 3, which is characteristic of Mg matrix. Some serration in the stress-strain curve at high strain can be correlated with RMS spikes. Elastic modulus values for these materials were similar, ranging from 181.6 GPa (26.4 msi) for P55Gr/Mg-1%Zr to 173.8 GPa (25.2 msi) for P55Gr/Mg-1%Mn, and in agreement with the values predicted by the rule of mixtures.

Transmission Electron Microscopy

- Interfacial integrity and dislocation substructure of cast Gr/Mg-Mn specimens were examined by transmission electron microscopy. It was noticed that the thin specimens prepared by ion milling were quite prone to oxidation when left in air for longer than 15 minutes. The oxidation of Mg matrix can be primarily attributed to its high purity, because in the presence of alloying elements, as in the matrix of Gr/AZ91C Mg, ion milled specimens remain stable in air for a few days.

In the inter-fiber matrix region shown in Figure 4, grain boundaries were observed perpendicular to the interface, and subgrains lay at random angles to the interface. Also, fine spheroidal and rod-like precipitates were observed along the grain boundaries and at the interface. The dislocation network near the interface is quite tangled, consisting primarily of two variants consistent with basal and pyramidal slip systems. The observations of various regions near the interface indicate generally high dislocation density which is quite comparable with the dislocation density predicted by G-L theory. The dislocations near the interface region are quite mobile due to the thermal stress generated by the incident beam in the TEM, as compared to Gr/Al specimens, making it difficult to conduct in situ deformation stage tests.

7.4 Investigations in Progress

• Damping Behavior of Metal Matrix Composites

- Both flexural (clamped-free and free-free) and extensional damping tests at low frequencies and low-to-intermediate strain amplitudes are being conducted and statistically verified for both as-cast and heat treated specimens.

• In Situ Characterization

Acoustic Emission

- Wire specimen geometry test are in progress to determine the correlation to low and intermediate stress level acoustic emission and microstructural changes. P55Gr/Mg-1%Mn and P55Gr/Mg-1%Zr precursor wires have been fabricated. Tensile tests will be interrupted at 20%, 40%, 60%, 80%, and 100% of failure load. Where AE source location indicates a localized event source, microstructural investigations will be conducted, particularly at the fiber-matrix interface. These data will be correlated with AE analysis to provide an understanding of the fiber-matrix interfacial phenomenon in Gr/Mg composites.
- Reliable reference AE data from Mg-1%Mn and Mg-1%Zr matrix alloy specimens are in progress to compare with the response from flat specimens.
- Experiments to determine the effects of the 800°F, 8 hour heat treatment upon the AE from the fiber-matrix interface are in progress on Gr/Mg-1%Mn specimens.

Transmission Electron Microscopy with Deformation Stage

- A TEM with deformation stage is being used to study the effect of strain upon the dislocation substructure, particularly with respect to dislocation motion that might be responsible for energy dissipation. Both Gr/Al and Gr/Mg composites will be studied. Preliminary investigations of this technique on Gr/Mg specimens have been complicated by difficulties with bonding of the specimen to the deformation stage.

7.5 Presentations

- SDIO/IST Advanced Composites Program Review at Woods Hole, MA, June 7, 1987.
- "Damping Mechanisms in Continuous Gr/Al Composites," to be presented at the American Ceramics Society Meeting, Cocoa Beach, FL, January 20-22, 1988.
- "Internal Friction in Cast Graphite-Magnesium Composites," to be presented at the Materials Research Society meeting in Reno, Nevada, April 5-8, 1988.

7.6 Technical Reports

- None

7.7 Publications

- None

7.8 Participants

<u>Name</u>	<u>Task</u>
Material Concepts, Inc, Columbus, OH	Flat cast composite panels
University of Illinois	TEM with deformation stage
University of Texas A&M, College Station, TX	Damping measurements
University of Denver, Denver, CO.....	Damping measurements
	In situ characterization
University of Wisconsin-Madison, Madison WI	In situ characterization

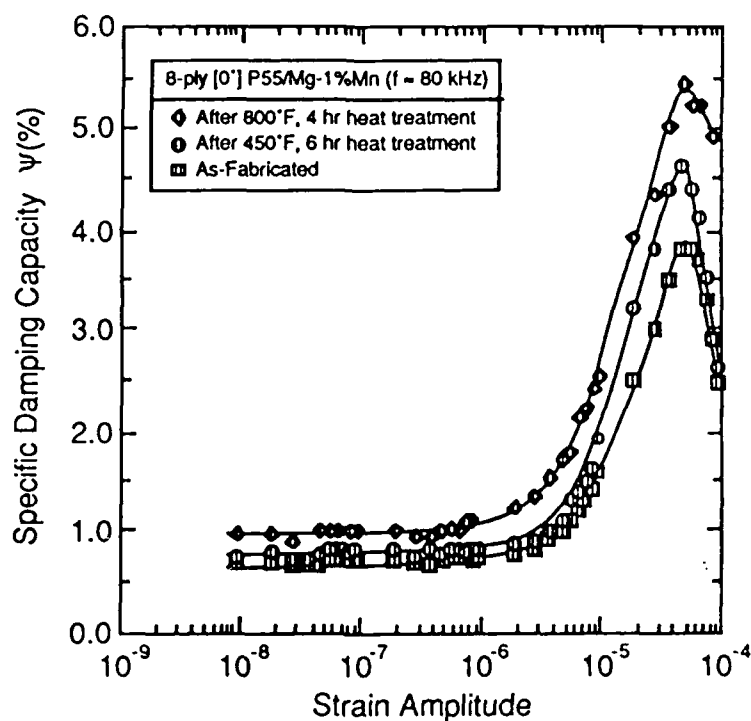


Figure 1
Damping Behavior of [0°] P55Gr/Mg-1%Mn in the As-Fabricated Condition, and After Heat Treatments of 450°F for 6 hours, and 800°F for 4 hours.

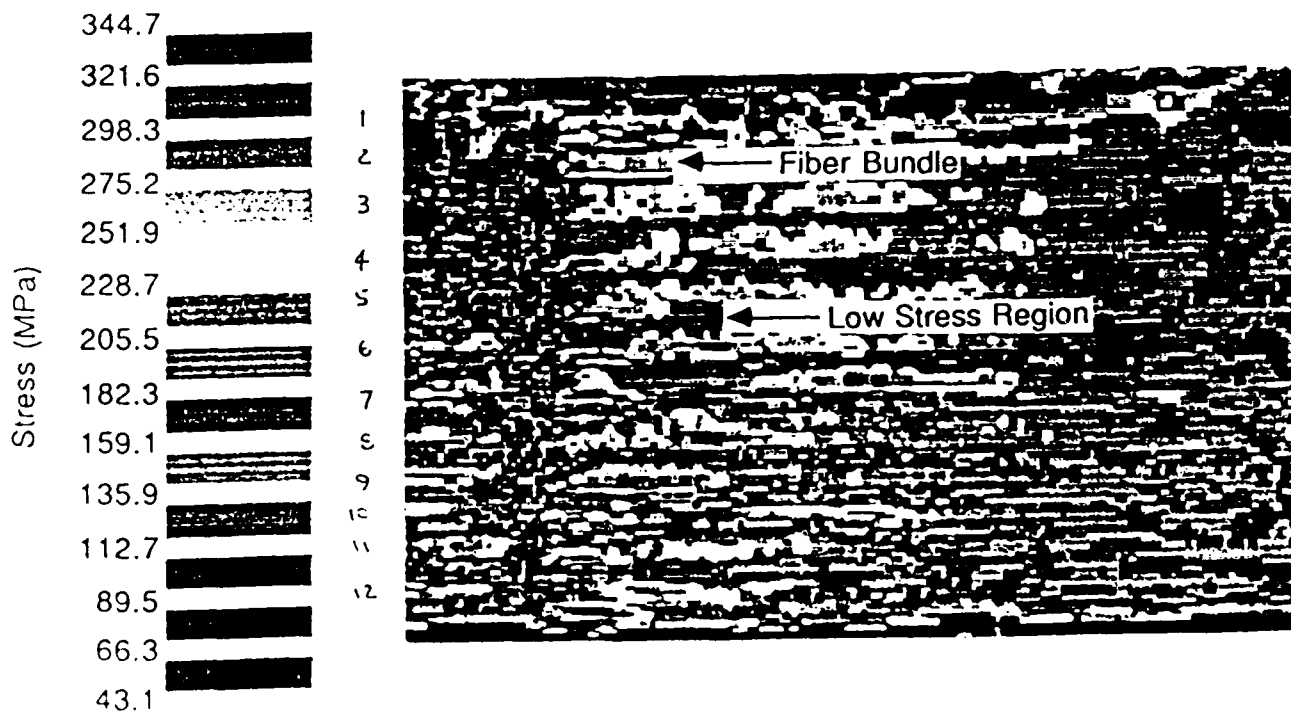


Figure 2
SPATE Image of the P55 Gr/Al Specimen Indicating High Stress Values Above the Graphite Fiber Bundles

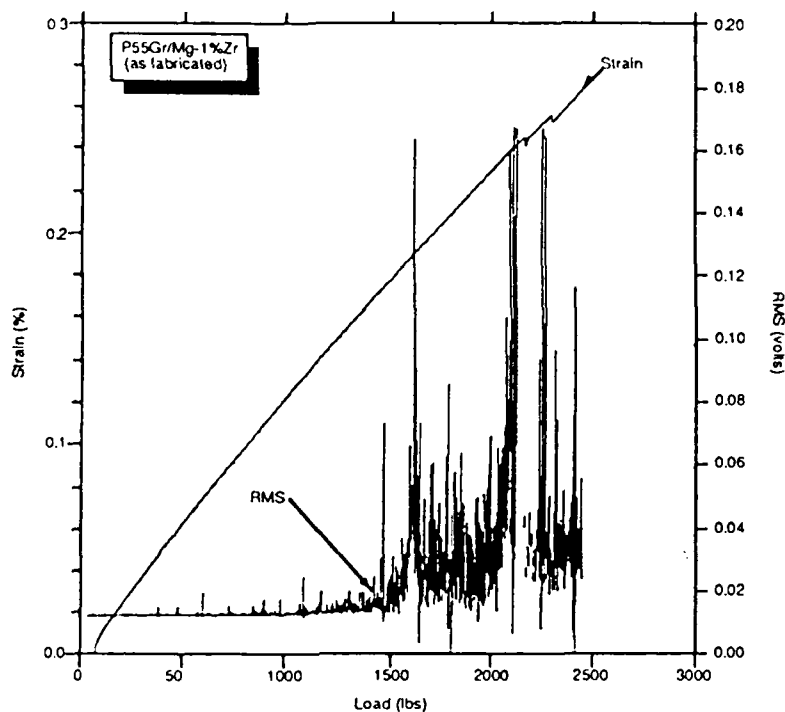


Figure 3
Acoustic Emission from Tensile Loading of As-cast P55Gr/Mg-1%Zr Indicating the Onset of AE Activity Upon the Deviation from Stress-Strain Linearity.



Figure 4
TEM Image of the Interfiber Matrix Region in As-Cast P55Gr/Mg-1%Mn Indicating High Dislocation Density and Grain Boundaries Perpendicular to the Interface.

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